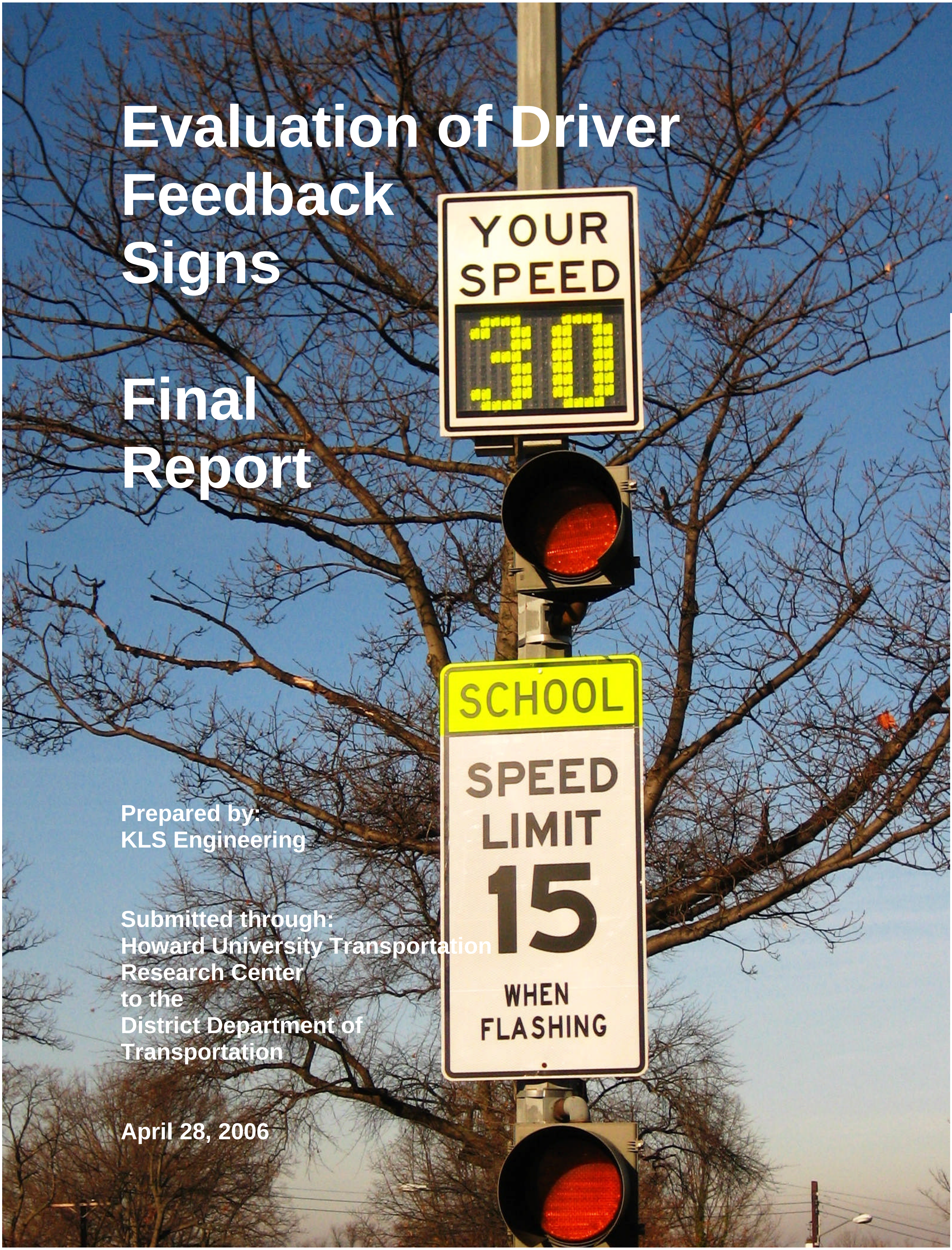
Evaluation of Driver Feedback Signs

Final Report



Prepared by:
KLS Engineering

Submitted through:
Howard University Transportation Research Center
to the
District Department of Transportation

April 28, 2006

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Prepared by:
KLS Engineering
21525 Ridgetop Circle, Suite 140
Sterling, VA 20166
(703) 444-7686

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Executive Summary

There is a well-established, positive relationship between vehicle speeds and the severity of pedestrian crashes. Encouraging drivers to drive at or below the posted speed limit is particularly important because driver error in the majority of pedestrian crashes is very high.

The District Department of Transportation (DDOT) is very concerned about pedestrian safety in general, and about the safety of children walking to school in particular. Many District schools have frontage on arterial streets with posted speed limits of 35 mph, and it is difficult for drivers to slow down and obey the school zone speed of 15 mph. This condition creates a hazardous traffic environment for school children. To reduce vehicle speeds around schools, DDOT has decided to install and evaluate Driver Feedback Signs (DFS) on an experimental basis. The DFS is a dynamic sign that uses radar to display real-time feedback about motorist vehicles' speed. By using this feedback, it is hypothesized that this feedback will compel motorists to obey the relevant speed limit and so reduce their vehicle speeds. Thus, the objective of this project is to evaluate the effectiveness of the DFS in causing motorists to comply with the posted speed in school zones and potentially improve pedestrian safety.

Five school zones were selected for installing and evaluating DFS - Raymond Elementary, Webb Elementary, Maury Elementary, Randle Highlands Elementary, and Stanton Elementary. The five study sites were selected using a combination of factors including pedestrian traffic, average daily traffic (ADT), history of pedestrian conflicts, vehicle speeds, citizen complaints, and coverage of several wards. The ADTs ranged from 10,000 to 30,000 vehicles.

A literature search revealed that the DFS are moderately used, and there are only a few rigorous research reports on their effectiveness. The information indicates that speed choice is a complex process, and the perceived speed of other drivers, the driving environment, the threat of enforcement, and their understanding of "normal" driving behavior may influence drivers.

The experimental design focused on safety and mobility surrogate measures of effectiveness (MOE) as pedestrian crashes are rare events and unlikely to occur during the short period of the study. Safety MOEs included the proportion of pedestrians in conflict with vehicles, the proportion of vehicles in conflict with pedestrians, and the proportion of braking drivers. Mobility MOEs included mean pedestrian delay and mean vehicle speeds. Data was collected before and after the deployment of the DFS to assist in evaluating the MOE. A customer satisfaction survey was also conducted to assess the extent to which the DFS improved the level of satisfaction of the users of that roadway system.

Results
The analysis of the pedestrian conflicts did not reveal any statistical significance between the proportion of pedestrian conflicts with vehicles or the vehicles in conflict with pedestrians before and after the deployment of the DFS. However, the data did indicate that pedestrian conflicts tend to increase as the number of travel lanes, traffic volume, and vehicle speeds increase.

Data related to braking drivers indicates a statistical significant difference in the before and after proportion of braking drivers at more than 50 percent of the locations. The data showed on average an increase of 42 percent in the frequency of braking drivers after the installation of the DFS. The largest increase occurred on roads with one lane in both direction and where the DFS view was unobstructed.

The analyses of the mobility measures of effectiveness such as pedestrian delays did not reveal any statistical significance in the before and after data. The analysis of the mean vehicle speeds indicated a statistical significant difference in the before and after data collected at just over 25 percent of the sites. However, on closer examination of the data, we observed that at 69 percent of the sites, the vehicle speeds were reduced by as much as 7 mph after DFS installation.

Customer Satisfaction
Prior to installing the DFS, at least 33 percent of all drivers on the surveyed roads operated their vehicles at or more than twice the school zone speed limit (15 mph), with over 95 percent traveling above it. At least 1 in 4 drivers did not know they were traveling within a school zone and so never adjusted their speeds. After installing the DFS, at least 46 percent of drivers indicated they observed the sign and 63 percent of these drivers adjusted their speed downward.

At least 64 percent of pedestrians on the surveyed roads rated the crossing facilities as below average and unsafe. Prior to installing the DFS, at least 3 in 4 pedestrians indicated that drivers generally do not yield to them in the pedestrian crossings and appear to be speeding. After DFS installation, more than 90 percent of pedestrians did not notice any change in vehicle speeds or feel any safer in crossing the street.

Conclusion
The results of field studies at the five school locations where the DFS were installed indicate that such displays may have a significantly higher proportion of braking drivers. While this results in slower vehicle speeds at most locations, the reduction is only significant at just over 25 percent of the time.

It is not recommended that the DFS be deployed at all school locations. However, based on the results of the field studies and together with the findings from other scientific studies[8,9], it is recommended that the DFS be deployed in school zones where a speed study indicates that the mean vehicle speeds are 35 mph or greater and the following conditions are also present:

- Locations where the visibility of the DFS is at least 150 to 200 ft and not blocked by trees, utility poles, or other obstacles.
- Locations with two-lane roads, one travel lane in each direction.
- At locations with more than one travel lane in each direction, the DFS should be located over each lane. If this is not practical, increase the DFS size 36 in by 48 in.
- Locations with no on-street parking (When on-street parking exists, increase the DFS size to 36 in by 48 in.)
- Locations where the DFS conveys a clear and real need for the drivers to reduce speed. Similarly, the DFS maybe less effective at locations with an overabundance of driver information for a driver to process or too much sign clutter

Finally, the DFS has good potential for reducing driver speeds and improving pedestrian safety when used as discussed above. However, an overabundance of DFS can also mitigate any positive effects they may have.

Background

Approximately 22 percent of the 163 traffic fatalities occurring in the District of Columbia during the 2002-2004 period involved pedestrians. Pedestrian injuries were approximately 8 percent (1,944) of all traffic injuries (25,062) during the same period. The District of Columbia pedestrian fatality rate of 2.2 persons per 100,000 persons is considered average when compared with other cities of similar population and size, such as Baltimore (2.2), MD, and Jacksonville (2.6), FL.

The District Department of Transportation (DDOT) is very concerned about the safety of children walking to school. School children, especially those in elementary grades, are vulnerable to pedestrian crashes. Because of their age, many lack good judgment for crossing the street and their smaller statue means they are not always visible to motorists. Some causes of pedestrian crashes in school zones include restricted sight distance, high approach speed, and high traffic volumes at critical crossing locations. In addition, many District schools have frontage on arterial streets with posted speed limits of 35 mph, and drivers do not slow down to the posted school zone speed of 15 mph. These conditions create a hazardous traffic environment for school children.

To reduce vehicle speeds around schools, DDOT decided to install and evaluate Driver Feedback Signs (DFS) on an experimental basis at five school zones. The DFS is a dynamic sign that uses radar to provide motorists real-time feedback about their vehicles' speed. It is hoped motorists will use this feedback and obey the relevant speed limits, which will enhance overall pedestrian safety around schools.

Objectives

The objective of this project is to evaluate the effectiveness of DFS in causing motorists to comply with the posted speed in school zones and thus potentially improve pedestrian safety. Pedestrian vehicle conflicts and driver braking are surrogate measures selected for evaluating whether DFS would improve pedestrian safety. Average pedestrian delay and vehicle speeds are also the surrogate measures selected for evaluating the impact on mobility. Pedestrian crashes are rare and random events and were excluded from the evaluation.

Project Phasing

The project was conducted in two phases. Phase 1 involved developing the evaluation methodology, collecting baseline data, and preparing a preliminary report. Phase 2 involved collecting the "after" data, customer survey, data reduction, and preparing this final report.

Literature Search

A brief literature search was undertaken using the World Wide Web, transportation databases such as TRIS and ITE, and questions were also posted on various list serves. The literature survey shows that DFSs are widely used. Table 1 summarizes school zone locations where DFSs were deployed in the United States and internationally. However, there were few rigorous research reports on their effectiveness. Some reports suffer from "weak methodologies," such as not controlling for external factors. Others, even though researchers collected before and after data, did not complete any statistical analyses. Table 1 shows jurisdictions deploying DFS that researchers contacted. Unfortunately, research at all locations, with the exception of College Station, TX, was conducted by local agencies. Generally, most local agencies do not have the financial or human resources to undertake a rigorous evaluation. However, the researchers received some anecdotal comments, which are summarized below.

Table 1: Summary of DFS Deployment

Country	Location	Year	Evaluated	No. of DFS	General Comments
NJ. USA	Hudson County	2005	No	2	No evaluation
CA, USA	Alameda County, Garden Grove	2004	Pending	Unknown 10	Pending Average speed reductions between 5.6 to 22 %
MN, USA	Washington Co., Anoka County	2004 2005	Ongoing No	3 18	_None_ No evaluation
AZ, USA	Phoenix	2003	Yes	2	Average speeds reduced by 7mph
OR, USA	Tigard	2003	No	1	Decrease in speeding violations
NH, USA	Concord	2003	No	1	No evaluation
CA, USA	Berkeley	2002	No	4	No evaluation
TX, USA	College Station	2003	Yes	1	Average speed decreased by 5 - 9 mph
WA,USA	King County	2001	Yes	4	Average speeds reduced by (-) 0.5 to 2.2 mph
Germany		1999	Yes	Unknown	None
UK	Newcastle, Durham	2003	Ongoing	10 2	85^{th} percentile reduced from 43 to 38 mph Maintain speeds

The reasons for speed choice are complex, but, Zaidel (1992)[1] suggests that any attempt to understand driver behavior must include the effect of the social traffic environment. The behavioral influence of other drivers is clear; it has been found that the perceived speed of other drivers is as important for speed choice. Drivers' comparisons of their own speed with the speed of drivers around them play a significant role in speed choice (Connolly and Aberg, 1993)[2]. Social comparison is another potential reason for speed choice. Social comparison has been little explored in the speeding context, although there is the tendency for drivers at travel at a speed similar to the lead vehicle (Aberg, 1993)[3]. Aberg claimed that speed choice plays a significant role in drivers' comparisons of their own speed with the speed of drivers around them. In making social comparisons, drivers may not accurately assess the speed of other vehicles. Aberg (1997)[4] found that drivers estimated the speed of other drivers to be 5 to 6 mph higher then the speed actually observed. This tendency for drivers to overestimate the speed of others suggests one reason why speeding maybe so prevalent. If drivers perceive that driving above the speed limit is the “norm,” they may view their own speed violations as “normal” driving behavior.

There has been limited research into how perceptions of driving norms can be changed to improve driver performance. Van Houten (1983)[5] reported that public posting of speeding information maybe one mechanism by which drivers will change their ideas about what speed is “normal” and will change their speed choice. Groeger and Chapman (1997)[6] conducted a series of experiments in a simulated setting in order further explore these explanations. Interestingly, they also found that the posted feedback speed was effective in reducing speeding, but only where the majority of other drivers present complied with the posted feedback information.

The City of Garden Grove (CA)[7] installed 10 DFS on roads at five (5) school locations in 2003. All DFS were installed on arterials streets with posted speed limits of 35 to 40 mph. Average daily traffic ranged from 8,000 to 29,200 vehicles. Data was collected on vehicle speeds before and after DFS installation. After installing the DFS, the City reported a significant reduction in the 85th percentile speeds from 5.6 to 22.3 percent. The DFS were installed over the travel lane and were clearly visible with no sign clutter.

In 2003, the Texas Department of Transportation (College Station)[8] installed DFS in one school zone and also upstream of a second school zone to transition motorists down to the school zone speed. Texas Transportation Institute (TTI) was contracted to evaluate the DFS. TTI reported average speeds reduced by 9 mph at the school zone and less than 3 mph in the transition zone. The influences of the DFS were found to differ depending on the speed of a motorist approaching the sign. Motorists traveling at higher speeds did appear to reduce their speed more significantly in response to the DFS then did motorists traveling at or below the posted speed limit The results conclude that good sight distance, single lane (per direction), and no sign clutter contributed to increased DSF effectiveness.

In 2001, King County (WA)[9] installed four DFSs in the vicinity of an elementary school along a collector arterial. To evaluate its effectiveness, the County staff conducted and analyzed speed studies before, during, and after DFS deployment. Findings indicate that installations closest to the school had the smallest change, possibly because that location already had the lowest average speeds. The average speeds were changed from (+) 0.5 to (-) 2.2 mph.

Many other jurisdictions reporting on DFS undertook no rigorous evaluations. DFS was installed on the main road at the Tigard (OR) High School. The average daily traffic was 10,000 vehicles, with a posted speed limit of 20 mph. Drivers were frequently ticketed for driving in excess of 40 mph before the DFS was installed. After DFS installation, there was a marked decrease in school zone speeding violations by 20 to 34 percent.

Ten DFS were installed at different locations in Doncaster (U.K.) where vehicular speeds were of prime concern. After DFS installation, vehicle speeds in an urban housing estate were reduced by 10 percent. In another location, DFS helped to reduce the 85th percentile from 43 to 38 mph. The authors of these reports concluded that clear DFS visibility, no sign clutter, and roads with one travel lane in each direction improved DFS effectiveness.

Research Methodology

Site Locations

Consultations with the DDOT identified five study sites to evaluate the DFS in the District of Columbia. Each street would have one DFS installed in either direction. The DFS would be added to existing school signs and flashers and operate under the same time constraints

Table 2: Study Site Locations

Study Site #	Elementary School	Address	Sign Location	No. of Lanes	Posted Speed Limit	Average Daily Traffic (~ADT)	Ward
1	Raymond	915 Spring Rd., NW	New Hampshire Avenue	4	30	16,000	W4
2	Webb	1375 Mount Olivet Rd., NE	Mount Olivet Road	4	25	20,000	W5
3	Maury	1250 Constitution Ave., NE	Constitution Avenue	2	25	10,000	W6
4	Randle Highlands	1650 30th St., SE	Pennsylvania Avenue	5	25	30,000	W7
5	Stanton	2701 Naylor Rd., SE	25th Street	2	25	12,000	W8

Study sites selected were based on a combination of factors including:

- Proximity of school to capture pedestrian traffic.
- Minimum average daily traffic of 10,000 vehicles.
- Agreement with the DDOT to install DFS.
- History of pedestrian conflicts.
- High vehicle speeds.
- Coverage of several wards.
- Citizen complaints.

Figure 1 shows the study site geographic locations.

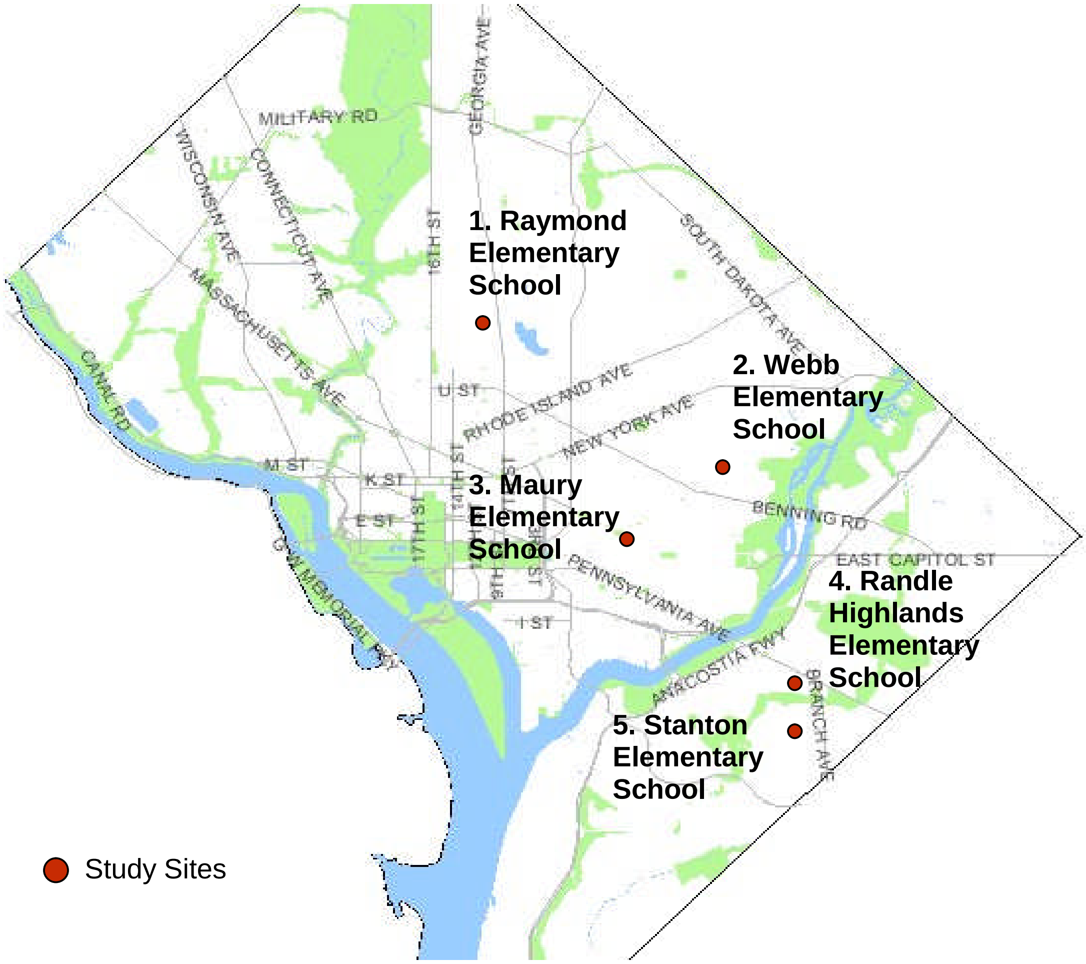

Figure 1: Location of Study Sites for Evaluating the DFS

Study Site # 1: Raymond Elementary School

Raymond Elementary School is located on Spring Road one block west of New Hampshire Avenue, NW, a major arterial with an ADT of more than 16,000 vehicles. Stop signs control Spring Road at its intersection with New Hampshire. Police officers serve as school crossing guards (see figure 2) on New Hampshire Avenue between 8:20 – 8:40 a.m. and 3:00 – 3:30 p.m. The officers usually stop the traffic on New Hampshire Avenue as they escort pedestrians across the intersection. Adult school crossing guards are also located at the intersections of 13th Street and 10th Street with Spring Road. The crosswalks on New Hampshire Avenue are visible and additional school warning signs and flashers are posted on the approaches. The sidewalk network is in good condition.

PO: Police Officer at Crosswalk O Study area

Figure 2: Raymond Elementary School

New Hampshire Avenue has four travel lanes (two each direction), with on-street parking (both sides) and a 6-ft center painted median. The overall roadway width of New Hampshire Avenue is approximately 56 ft.

Between 1999 and 2003, nine crashes occurred within the school zone on New Hampshire Avenue. None of these crashes involved pedestrians.

Study Site # 2: Webb Elementary School

Webb Elementary School is located on Mt. Olivet Road, east of Holbrook Street, NE, a minor arterial with more than 20,000 ADT. Sidewalks are only available on the south side of Mount Olivet. Pedestrians do not cross Mount Olivet Road between Holbrook Street and Trinidad Avenue, as there are no sidewalks or other pedestrian facilities on the north side. An adult school-crossing guard is located at the intersection of Bladensburg Road and 17th Street. There are signalized intersections at Bladensburg Road, Trinidad Avenue, and West Virginia Avenue with Mount Oliver Road. Figure 3 shows advanced school signs and flashers posted on both sides of Webb Elementary School along Mount Olivet Road. The sidewalk network is in good condition.

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ASCG: Adult School Crossing Guard O Study area

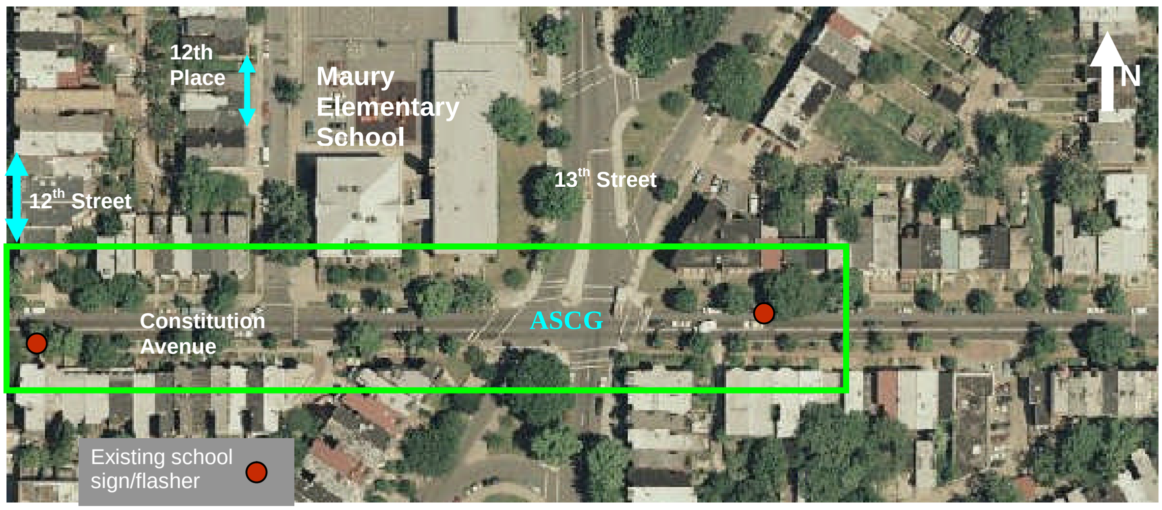
Figure 3: Webb Elementary School

Mount Olivet Road has four travel lanes (two lanes in each direction). No parking or stopping is allowed on Mount Olivet Road between 7:00 – 9:30 a.m. and 4:00 – 6:30 p.m., and there is no parking between 9.00 – 4.00 p.m. on school days. The overall roadway width of Mount Olivet Road is approximately 44 ft.

Between 1998 and 2002, more than 167 crashes occurred along Mount Oliver Road between the intersections of Bladensburg Road to West Virginia Avenue (inclusive). Crashes, but pedestrians were involved in fewer than seven (7).

Study Site # 3: Maury Elementary School
Maury Elementary School is located at the intersection of Constitution Avenue and 13th Street, NE. Constitution Avenue is a minor arterial with more than 10,000 ADT. A good sidewalk networks exist on both sides of Constitution Avenue. An adult school-crossing guard is located at Constitution Avenue and 13th Street. This intersection is signalized but has no pedestrian signals. The crosswalks on Constitution Avenue are highly visible and in good condition. Additional school signs and flashers are located just east of 12th Street and west of Warren Street along Constitution Avenue (see figure 4).

Constitution Avenue has two travel lanes (one in each direction) with parking on the north side only. However, during the morning peak period from 7.00 – 9.30 a.m., Constitution Avenue is one-way westbound. The overall roadway width of Constitution Avenue is approximately 30 ft.



ASCG: Adult School Crossing Guard O Study area

Figure 4: Maury Elementary School

From 1998 to 2002, over 22 vehicular crashes occurred within the school zone along Constitution Avenue, between the intersections of 12th Street and 13th Street. However, fewer than 2 crashes involved pedestrians.

Study Site # 4: Randle Highlands Elementary School
Randle Highlands Elementary School is located on 30th Street, SE, just south of Pennsylvania Avenue, a principal arterial with an ADT close to 30,000 vehicles. A good sidewalk network exists on both sides of Pennsylvania Avenue. An adult school-crossing guard is located at the intersection of 30th Street and Pennsylvania Avenue, which is also signalized. The traffic signal system includes pedestrian signals with countdown timers.

As figure 5 illustrates, advanced school signs and flashers are posted on both sides of Randle Highland Elementary School along Pennsylvania Avenue. Pennsylvania Avenue has four travel lanes (two each direction) and one reversible center lane. Pennsylvania Avenue is approximately 50 ft wide with no on-street parking.

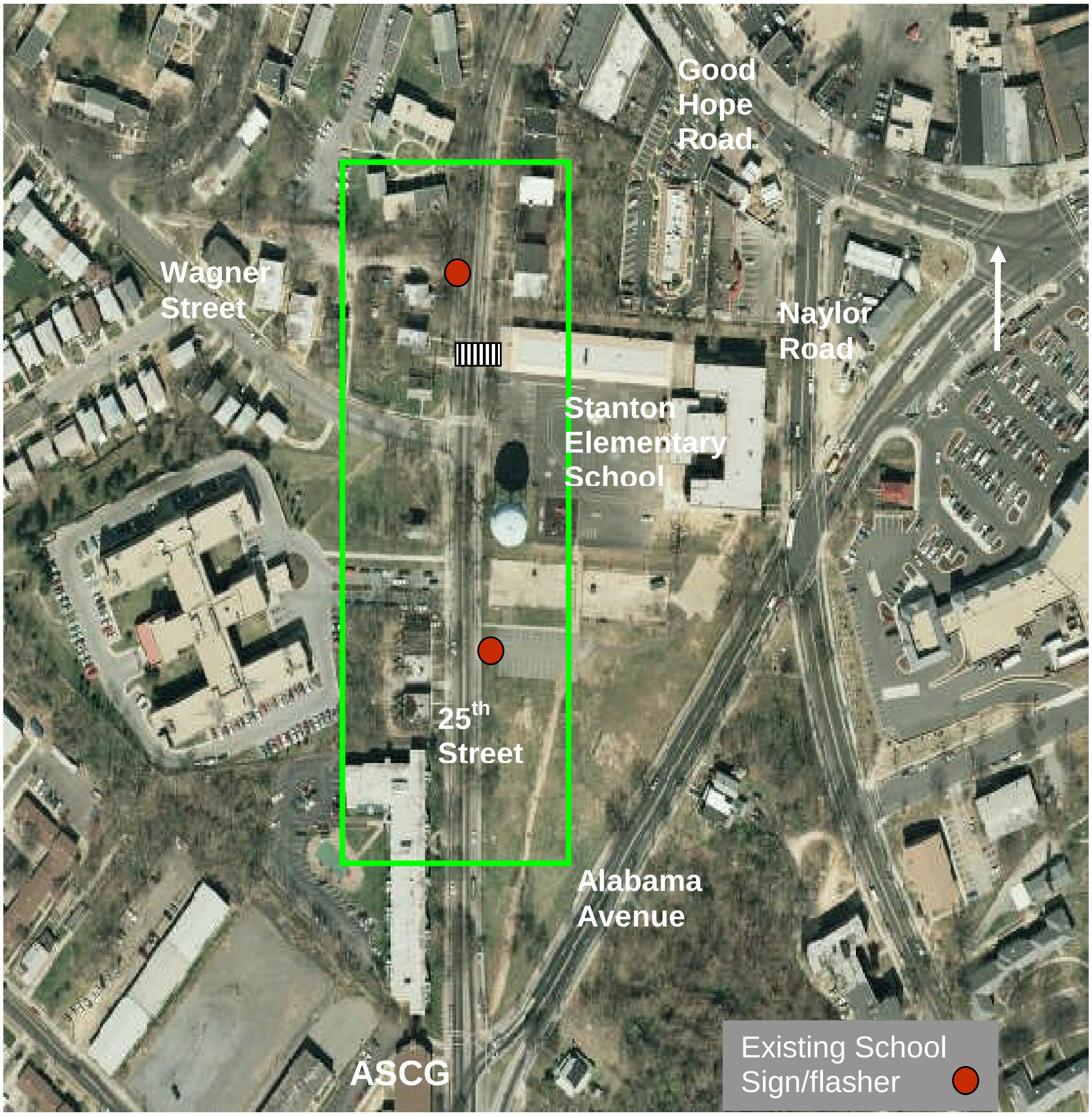
ASCG: Adult School Crossing Guard O Study area

Figure 5: Randle Highlands Elementary School

Between 1998 and 2002, more than 53 vehicular crashes occurred within the school zone along Pennsylvania Avenue. No pedestrian crashes occurred.

Study Site # 5: Stanton Elementary School

Stanton Elementary School is located between 25th Street and Naylor Road, SE. Stanton Elementary School is at the confluence of four minor arterial roadways (Naylor Road, Good Hope Road, Alabama Avenue, and 25th Street). The ADT is 12,000 vehicles. An adult school-crossing guard is located at the intersection of Alabama Avenue and 25th Street. Traffic signals are present at the intersections of Good Hope Road and Alabama Avenue with 25th Street.



ASCG: Adult School Crossing Guard **O** Study area

Figure 6: Stanton Elementary School

As figure 6 shows, advanced school signs and flashers are posted on both sides of Stanton Elementary School along 25th Street. A good sidewalk network exists, but it needs significant maintenance. A crosswalk exists on 25th Street just north of the school entrance. On 25th Street there are two travel lanes (one in each direction) in the vicinity of the school. Parking is allowed on both sides of 25th Street just north of school. The roadway width of 25th Street is approximately 36 ft.

Between 1998 and 2002, nine vehicular crashes occurred within the school zone on 25th Street; only one was a pedestrian-related crash.

Experimental Design

This section outlines the experimental design goals, hypotheses, and measures of effectiveness (MOEs) for evaluating the DFS. The goals were related to safety and vehicle mobility. The hypotheses associated with each goal formed the basis for testing and measuring the impact of the DFS sign. The MOEs associated with each hypothesis provided the basis for comparison of "before" and "after" (or "with" and "without") deployments. The Microsoft Excel program was used for all statistical analyses.

Approach to Data Collection and Analysis

Data was collected during the morning (7.00 a.m.—9.00 a.m.) and afternoon (2.00 p.m.— 4.00 p.m.) peak periods at all five sites on school days. The researcher team collected a minimum of 40 hours of data at each DFS location. The "before" (or baseline) data collection was completed between November (2004) and January 2005. The "after" data collection took place between June 2005 and November 2005.

The prime MOE was vehicle speeds. Secondary MOEs include the proportion of pedestrian conflicts and braking drivers. Researchers conducted two surveys, a pedestrian attitude survey to assess their opinion regarding safety and the DFS and a driver feedback survey to assess driver understanding and compliance with the DFS. The following MOEs were identified as relevant to testing the hypotheses for the safety and mobility goals. Each MOE is defined; the data collection methods are described (when necessary); specific data requirements are noted; the data reporting formats are specified; and the analysis methods are discussed.

- Safety MOEs.
- Mobility MOEs.
- Customer Satisfaction.

Safety MOEs

Qualitative data was collected before and after the deployment of the DFS. The following safety MOEs were identified as relevant to assessing the safety impacts of the DFS and the proportion of:

- Pedestrians experiencing conflict with vehicles.
- Vehicles in conflict with pedestrians.
- Braking drivers.

Table 3 summarizes the safety MOEs associated with the objectives and hypotheses for the DFS.

Table 3: Safety MOEs

Objectives	Hypothesis	Measure of Effectiveness	Data Source	Analysis
Assess the impact of the DFS on safety surrogates	DFS will have no difference in the proportion of pedestrian-vehicle conflicts DFS will have no difference in the proportion of braking drivers	a. Proportion of pedestrian experiencing conflict with vehicles. b. Proportion of vehicles in conflict with pedestrians a. Proportion of braking drivers	Before and After data collected and analyzed for the selected locations	Comparison of data before and after implementation of DFS

Because crashes are rare events, they were unlikely to occur during the short period of the study. Thus, the data for evaluating change in crashes was not attainable in the duration of the data collection period. It is common practice to use surrogate measures for crashes when it is unlikely crash data will be able to provide information for evaluating the effectiveness of a countermeasure. The idea of surrogate measures is that if it can be shown that a countermeasure reduces, for instance, an unsafe behavior (e.g., pedestrians crossing during the solid DON'T WALK signal phase), then potential crashes are also likely to be reduced.

<u>Pedestrian-Vehicle Conflicts</u>

A conflict involves an evasive action by a motorist or pedestrian, where they are on a collision course. A motorist may take evasive action such as stopping, reducing speed, or swerving to avoid impact with the pedestrian. The pedestrian action may include stepping or leaping back, or running forward to avoid being struck by a vehicle.

Data Collection Method

For a conflict to be scored, researchers must have observed evasive action (by either motorist or pedestrian). All conflicts occurring from 50 ft upstream of the DFS (proposed location in baseline case) and a point 200 ft downstream of the DFS were recorded before and after implementation. The area was marked off in 50-ft grids using orange cones positioned out of the motorists' line of sight so as not to attract their attention. Two technicians were trained so that their understanding of a conflict was consistent with what is described above. These technicians were used at all sites.

Data Reporting Format

The following data was reported both before and after deployment of the countermeasure:

- Proportion (P_p) of pedestrians experiencing conflicts with vehicles

$$P_p = \frac{\text{Pedestrians experiencing conflict}}{\text{All pedestrians}}$$

- Proportion (P_v) of vehicles in conflict with pedestrians (traffic volumes was collected at the same time so that this relationship could be established)

$$P_v = \frac{\text{Vehicles in conflict with pedestrians}}{\text{All vehicles}}$$

Data Analysis Methods

A z-test (t) was used to test the difference in the proportion of both occurrences before and after deployment—pedestrians experiencing conflict with vehicles and vehicles in conflict with pedestrians.

Braking Drivers

The proportion of braking drivers is the number of drivers who reduce speed as shown by their brake lights being illuminated compared to all vehicles within that same time period.

Data Collection Method

This MOE was measured in the area between the location of the DFS and a point 200 ft downstream of the DFS. Visible identification markers placed at the intervals designated the data collection area. All braking drivers (as indicated by their brake lights being on) within the data collection area were scored. Only the first vehicle in a vehicle queue was scored as braking (no vehicles queued behind the braking vehicle was scored as braking, neither were they counted as a vehicle present in the calculation). Traffic volumes were collected at the same time to establish this relationship. Two technicians were trained in collecting this data and used at all sites.

Data Reporting Format

The following data was reported both before and after countermeasure deployment :

- Proportion of braking drivers (P_{bd})

$$P_{bd} = \frac{\text{Number of drivers braking}}{\text{All drivers}}$$

Data Analysis Methods

Researchers used a z-test (t) to test the difference in the proportion of occurrences of braking drivers before and after DFS deployment.

Mobility MOEs

While safety is of vital importance, the effect of the DFS on mobility is also important. Ideally, the DFS would improve pedestrian safety, pedestrian mobility, and not adversely effect vehicle mobility. Data collected included vehicle speeds, vehicle volumes, and pedestrian delays at crossing. The following MOEs were identified as relevant to assessing the mobility impacts of the DFS:

- Mean pedestrian delay and
- Mean vehicle speed

Table 4 summarizes the mobility MOEs associated with the objectives and hypotheses for the DFS.

Table 4: Mobility MOEs

Objectives	Hypothesis	Measure of Effectiveness	Data Source	Analysis
Assess the impact of the DFS on pedestrian mobility	DFS will have no difference on mean pedestrian delay	Mean pedestrian delay	Before and After data collected and analyzed for the selected locations	Comparison of data before and after DFS implementation f
Assess the impact of the DFS on vehicle mobility	DFS will have no difference on mean vehicle speeds	Mean Vehicle speed	Before and After data collected and analyzed for the selected locations	Comparison of data before and after DFS implementation

<u>Pedestrian Delay</u>

Pedestrian delay is defined as the average time a pedestrian has to wait before he/she can begin crossing the street, plus any additional delay the pedestrian experiences while crossing. An example of the latter, a pedestrian trapped in the roadway cannot complete the crossing maneuver. This delay experienced by the pedestrian while waiting to complete the crossing maneuver is added to the delay the pedestrian experienced before crossing (if any) to establish the total pedestrian's delay.

Data Collection Method

Pedestrian delay was measured in the area between the location of the crosswalk and a point 50 ft upstream and downstream of the crosswalk. Visible marking was placed at the 50-ft mark to designate the data collection area. The delay was recorded for all pedestrians crossing within the data collection area.

To record pedestrian delay, the delay was assumed to start when the pedestrian was first oriented to make the crossing and ends at completion of the crossing maneuver. Two technicians were trained in recording this data and they were used at all the sites.

Data Reporting Format

The following data was reported both before and after DFS deployment:

- Mean pedestrian delay.

Data Analysis Methods

A Student's t-test was used (n<30) to test the difference in the mean pedestrian delays before and after the DFS deployment.

Vehicle Speed

Vehicle speed is the speed of a vehicle at a particular location.

Data Collection Method

Technicians used hand-held radar detectors to measure vehicle speeds 50 ft downstream of the DFS. When this sign was deployed in the vicinity of a marked mid-block and/or unsignalized intersection, technicians measured vehicle speeds 50 ft in advance of the nearest downstream marked crosswalk. When the DFS was deployed in the vicinity of signalized intersections, vehicle speeds was measured 50 ft downstream of the DFS on the green light.

Data Reporting Format

The following data was reported both before and after the deployment of the DFS at each location:

- Mean vehicle speed.

Data Analysis Methods

A z-test (t) was used to test the difference in the mean vehicle speeds before and after the DFS deployment.

Customer Satisfaction

Customer satisfaction focused on the extent to which the DSF improved the level of satisfaction with the users of that roadway system. Pedestrian and drivers were the primary users of the affected roadway system. Thus, it was critical to measure satisfaction levels among both pedestrians and drivers to evaluate overall customer satisfaction. Brief survey instruments were developed and administered to pedestrians and drivers after DSF installation.

The customer satisfaction evaluation was focused on three key objectives:

- Ease with which users (as defined above) notice, understand, and comply with the DSF.
- User perception of pedestrian and driver safety in the overall context of the selected roadway system.
- User perception of driver and pedestrian mobility in the overall context of the selected roadway system.

Table 5 summarizes the Customer Satisfaction approach for the DSF.

Table 5: Customer Satisfaction

Objectives	Hypothesis	Measure of Effectiveness	Data Source	Analysis
Assess ease with which drivers notice, understand, and comply with the DFS	Drivers will easily notice, understand and comply with the DSF	Driver feedback	Driver feedback survey	Analysis of feedback data
Assess pedestrian perception of their safety after DFS deployment	Pedestrians will observe improvements in their safety	Pedestrian feedback	Pedestrian attitude survey	Analysis of feedback data

Driver Feedback
The driver feedback survey contained brief questions in four areas:

- Trip purpose.
- Demographic information.
    - Gender (observation).
    - Age.
    - Residence.
    - Frequency of driving on the surveyed roads.
- Driver understanding and compliance to the existing traffic controls.
    - Knowledge of speed limit on roadway.
    - Knowledge of existing school zone and related speed limits.
    - Driver speed.
- Driver understanding and reaction to the DFS.
    - Driver observation of DFS.
    - Accuracy of DFS.
    - Driver reaction to their speed as shown on the DFS.

Pedestrian Attitude
The pedestrian attitude survey contained brief questions in five areas:

- Trip purpose.
- Demographic information.
    - Gender (observation).
    - Age.
    - Residence.
    - Frequency of walking along surveyed roads.
- Walking environment.
    - Safety.
    - Convenience.
    - Use (of crossing facilities).
    - Sidewalk width and condition.

- Driver behavior prior to installation of DFS.
    - Yielding for pedestrians.
    - Driver speeds.
- Driver behavior after installation of DFS.
    - Yielding for pedestrians.
    - Driver speeds.
    - Pedestrian perception of any driver behavioral change/s.

Data Analysis Methods

The data was analyzed by comparing the user response to certain questions, and the percentage of respondents for each response. Appendix A includes the survey instrument.

Results/Discussion

The results are organized by the following measures of effectiveness:

- Safety.
- Mobility.
- Customer Satisfaction.

Table 6 shows the reference for locations 1 through 5:

Table 6: DFS Locations

Loc. #	Elementary School	Address	Sign Location	No. of Lanes	Posted Speed Limit	Average Daily Traffic (~ADT)	Ward
1	Raymond	915 Spring Rd., NW	New Hampshire Avenue	4	30	16,000	W4
2	Webb	1375 Mount Olivet Rd., NE	Mount Olivet Road	4	25	20,000	W5
3	Maury	1250 Constitution Ave., NE	Constitution Avenue	2	25	10,000	W6
4	Randle Highlands	1650 30th St., SE	Pennsylvania Avenue	5	25	30,000	W7
5	Stanton	2701 Naylor Rd., SE	25th Street	2	25	12,000	W8

Safety Measures of Effectiveness:

Because crashes are rare events, they were unlikely to occur during the short period of the study. Thus, the data for evaluating change in crashes was not attainable in the duration of the data collection period. The following safety surrogate MOEs were identified as relevant to assessing the safety impacts of the DFS and were based on the portion of:

a. Pedestrians experiencing conflict with vehicles.
b. Vehicles in conflict with pedestrians.
c. Braking drivers.

A pedestrian-vehicle conflict involves an evasive action by a motorist or pedestrian on a collision course. A motorist takes evasive action such as stopping, reducing speed, or swerving. A pedestrian will suddenly steps back, leaps back, or runs forward to avoid being struck by a vehicle. In a review of the sites, researchers observed an increase in pedestrian conflicts at sites where the roadway had at least 4 through lanes, on-street parking, no medians, small traffic gaps, and good vertical and horizontal alignments.

a. Proportion of pedestrians experiencing conflicts with vehicles

Table 7 is a summary of the statistics for the proportion of pedestrians experiencing conflicts with vehicles. A two-proportion z-test was used to address the following null hypothesis: There is no significant difference in the proportion of pedestrians experiencing conflicts with vehicles before and after the deployment of the DFS (at the 0.05 level of significance).

Data was not collected at three locations. At location 2 (Webb Elementary School), no pedestrians crossed Mount Olivet Road, primarily as a result of the lack of pedestrian facilities and/or pedestrian destinations on the north side of Mount Olivet Road. At location 3 (Maury Elementary School), the school crossing guard did an excellent job in assisting students to cross Constitution Avenue and 13th Street. At location 4 (Randle Highlands Elementary School), the west-bound direction traffic backs up within the school zone on Pennsylvania Avenue through 30th and 31st Street intersections between 6.45 a.m. and 9.30 a.m. This is typical for the morning peak period traffic proceeding west into the District. The adult school-crossing guard also did an excellent job in assisting pedestrians crossing Pennsylvania Avenue during the morning and afternoon periods. No pedestrian conflicts were observed at any of these locations.

Table 7: Summary of data for pedestrians experiencing conflict with vehicles

		A.M. Period						**P.M. Period**					
Location		**Before**		**After**			**Significant** [1]	**Before**		**After**			**Significant** [1]
No.	**Direction**	**SS**	**P_{PB}**	**SS**	**P_{PA}**	**Z-score**	**Yes/No**	**SS**	**P_{PB}**	**SS**	**P_{PA}**	**Z-score**	**Yes/No**
1	Northbound	56	0.18	58	0.17	-0.09	No	46	0.17	50	0.16	-0.18	No
	Southbound	70	0.20	64	0.25	0.69	No	64	0.19	60	0.17	-0.30	No
3	No Data												
4	No Data												
5	Northbound	68	0.21	70	0.23	0.32	No	72	0.08	68	0.09	0.10	No
	Southbound	64	0.16	54	0.19	0.42	No	66	0.09	88	0.9	0	No

SS - Sample Size

P_{PB} - Proportion of pedestrians experiencing conflict with vehicles before DFS deployment

P_{PA} - Proportion of pedestrians experiencing conflict with vehicles after DFS deployment

1 - Significance level 0.5 (Z_c = 1.96)

Conflicts were observed to occur for one in every five pedestrians crossing New Hampshire Avenue (# 1) at its intersection with Spring Road (within 50 to 100 ft of the crosswalk). The morning peak period traffic had a higher percentage of work-related vehicle trips; thus, the drivers are more conscious of their time, which in turn may contribute to their being less cautious and result in a greater proportion of pedestrian-vehicle conflicts.

Pedestrian Vehicle Conflicts occurring on 25th Street (# 5) at the mid-block pedestrian crossing during the morning peak (one in every five pedestrians) are more than twice those that occur during the afternoon peak period (one in twelve). As discussed previously, the morning peak period traffic comprises a higher percentage of work-related trips, in-addition, 25th Street is used as a cut-through to Good Hope Road, which increases traffic volumes. Cut-through traffic generally travels at higher speeds and are less cautious to traffic control devices. These issues all contribute to a higher proportion of pedestrian experiencing conflicts with vehicles.

The z scores as shown in table 7 are less than 1.96 and greater then -1.96; thus accepting the null hypothesis that there is no significant difference in the proportion of pedestrians experiencing conflicts with vehicles before and after the deployment of the DFS (at the 0.05 level of significance).

b. Proportion of vehicles experiencing conflict with pedestrians

Table 8 is a summary of statistics for the proportion of vehicles experiencing conflicts with pedestrians. A two-proportion z-test was used to address the following null hypothesis: There is no significant difference in the proportion of vehicles experiencing conflicts with pedestrians before and after the deployment of the DFS (at the 0.05 level of significance).

As discussed previously, no data was collected from locations 2, 3, and 4. The Z scores shown in table 8 are less than 1.96 and greater then -1.96; thus accepting the null hypothesis that there is no significant difference in the proportion of vehicles experiencing conflicts with pedestrians before and after the deployment of the DFS (at the 0.05 level of significance).

Table 8: Summary of data for vehicle experiencing conflict with pedestrians

		A.M. Period						P.M. Period					
Location		Before		After			Significant [1]	Before		After			Significant [1]
No.	Direction	SS	P_{PB}	SS	P_{PA}	Z-score	Yes/No	SS	P_{PB}	SS	P_{PA}	Z-score	Yes/No
1	Northbound	856	0.01	750	0.01	0.3	No	1450	0.01	1334	0.01	0.17	No
	Southbound	2264	0.01	2066	0.01	0.61	No	1024	0.01	956	0.01	-0.26	No
3	No Data												
4	No Data												
5	Northbound	1000	0.01	1100	0.01	0.11	No	540	0.01	564	0.01	-0.07	No
	Southbound	496	0.02	340	0.03	0.86	No	566	0.01	550	0.02	0.60	No

SS - Sample Size

P_{PB} - Proportion of vehicles in conflict with pedestrians before DFS deployment

P_{PA} - Proportion of vehicles in conflict with pedestrians after DFS deployment

1 - Significance level 0.5 (Z_c = 1.96)

c. Proportion of braking drivers

Researchers scored all drivers who reduce speed, as shown by their brake lights being illuminated within an area 200 ft downstream of the DFS. Only the first vehicle in a queue of vehicles was scored as braking (no vehicles queued behind the braking vehicle was scored as braking).

The proportion of braking drivers (P_{bd}) is expressed as:

$$P_{bd} = \frac{\text{Number of braking drivers}}{\text{All drivers}}$$

Table 9 summarizes the statistics for the proportion of braking drivers. A two-proportion z-test was use to address the following null hypothesis: There is no significant difference in the proportion of braking drivers before and after the deployment of the DFS (at the 0.05 level of significance).

No data was collected at certain time intervals for locations 2, 3 and 4 for a number of reasons, including traffic congestion, one-way restrictions during the morning peak period, and the DFS being situated too close to a signalized intersection. Every location experienced some improvement in the proportion of braking drivers as table 9 shows. However, only 11 of the 16 locations where data was available were the z-scores were above the Z critical (1.96 > Z critical > -1.96) at a level of confidence of 95 percent. This implies that the null hypothesis is rejected at those 11 locations and there is a significant difference in the proportion of braking drivers before and after DFS deployment (at the 0.05 level of significance).

Table 9: Summary of data for proportion of braking drivers

		A.M. Period						P.M. Period					
Location		**Before**		**After**			**Significant [1]**	**Before**		**After**			**Significant [1]**
No.	**Direction**	**SS**	**P_{PB}**	**SS**	**P_{PA}**	**Z-score**	**Yes/No**	**SS**	**P_{PB}**	**SS**	**P_{PA}**	**Z-score**	**Yes/No**
1	Northbound	856	0.12	750	0.17	3.96	Yes	1450	0.08	1334	0.11	2.67	Yes
	Southbound	2264	0.02	2066	0.04	3.14	Yes	1024	0.04	956	0.06	2.37	Yes
2	Westbound	1500	0.03	1594	0.07	4.47	Yes	1160	0.04	1142	0.06	2.66	Yes
	Eastbound	No Data											
3	Westbound	2380	0.02	2446	0.04	3.12	Yes	800	0.02	902	0.03	2.04	Yes
	Eastbound	No Data						450	0.11	706	0.10	-0.81	No
4	Westbound	No Data						1049	0.08	1047	0.12	2.48	Yes
	Eastbound	625	0.10	663	0.13	1.74	No	1481	0.05	1650	0.06	1.30	No
5	Northbound	1000	0.05	1100	0.07	1.72	No	540	0.09	564	0.13	2.45	Yes
	Southbound	496	0.03	340	0.06	2.91	Yes	566	0.09	550	0.12	1.34	No

SS - Sample Size

P_{PB} - Proportion of braking drivers before DFS deployment

P_{PA} - Proportion of braking drivers after DFS deployment

1 - Significance level 0.5 (Z_c = 1.96)

It was observed that roads with two lanes (one lane per direction) had the highest proportion of braking in relation to the DFS. In addition, the afternoon period had an increase of more than 30 percent in the proportion of braking drivers. This can be attributed to the fact that drivers are more relaxed in the afternoon and their trips are not time based (non-work). Across all sites, the overall increase in the proportion of braking drivers was 42 percent after DFS deployment.

Drivers brake 50 to 100 percent more in the northbound direction of New Hampshire Avenue (# 1) when compared to the southbound direction. Possible explanations include the residential "look and feel" in the vicinity of the DFS when compared to the commercial nature further north toward Georgia Avenue and better visibility of the DFS.

The effectiveness of the DFS is reduced in the southbound direction (New Hampshire Avenue) as the sign is offset at least 15 ft from the nearest travel lane, and buses pull into and leave the nearby bus stop often blocking its visibility.

Drivers traveling westbound on Mount Olivet Road (# 2) brake 50 ft on either side of the DFS location. One possible explanation for this behavior is that drivers observe the school flasher and school simultaneously, and thus take immediate action.

Braking driver behavior on Constitution Avenue (# 3) during the afternoon peak period is at least 200 percent better than during the morning peak period. One possible explanation is that Constitution Avenue is one way west from 7:00 to 9:30 a.m., and the trips are mainly work related, motorists are focused on getting to their destination, and thus pay less attention to the existing traffic controls. In addition, the DFS in the westbound direction is not fully visible and on-street parking further separates the DFS from the travel lanes.

Braking drivers on Pennsylvania Avenue (# 4) generally do so within 0 to 100 ft upstream of the DFS. The eastbound direction in the morning peak period and the westbound direction in the evening peak period experienced a higher proportion of braking. This can be explained as these directions each have two through lanes with no on-street parking and the DFS is offset from the nearest travel lane by 2 ft.

Braking drivers on 25th Street (# 5) during the afternoon peak period seem to be more than twice that occurring during the morning peak period. Most drivers brake within 150 ft of the DFS in the northbound direction and within 50 to 100 ft in the southbound direction. The increase proportion of braking drivers in the northbound direction is attributed to better sign visibility, one travel lane, no on-street parking, and the DFS being offset from the travel lane approximately 4 ft.

Mobility MOEs

While safety is of vital importance, the effect of the DFS on mobility is also important. Ideally, the DFS would improve pedestrian safety, pedestrian mobility, and not adversely impact vehicle mobility. The research team identified two surrogate MOEs as relevant to assessing the mobility impacts of the DFS signs:

- Pedestrian Delay
- Vehicle Speed

Pedestrian Delay

Pedestrian delay is defined as the average time a pedestrian has to wait before he/she can begin crossing the street, plus any additional delay the pedestrian experiences while crossing. An example of the latter, a pedestrian is trapped in the roadway and cannot complete the crossing maneuver.

In general, the average observed pedestrian delay at most sites was less than 10 seconds. The DFS appeared to have no effect on pedestrian delay at the sites. The data also revealed that the average pedestrian delay at Randle Highlands Elementary School was more than five times the average delay at all sites. On closer examination of the data, researchers believe this result in part from traffic congestion occurring during the morning peak period (where vehicles are backed through the intersection) and the long signal phasing (in excess of 100 seconds). Because of these observed abnormalities, researchers excluded Randle Highland Elementary School from the analysis of the sites for pedestrian delay.

Table 10 is a summary of the statistics for the mean pedestrian delay. A student's t-test was used to address the following null hypothesis: There is no significant difference in the mean pedestrian delays before and after the deployment of the DFS (at the 0.05 level of significance). No data was collected from location 2 (Webb Elementary School) as no pedestrians were observed crossing the roadway. The t score is equal to 0.36 with the t critical being 2.14 at a level of confidence of 95 percent. Thus, the null hypothesis is accepted that there is no significant difference in the mean pedestrian delays being experienced at the locations before and after the deployment of the DFS.

Table 10: Mean Pedestrian Delay before and after DFS deployment

Location		Mean Pedestrian Delay	
No.	Direction	Before	After
1	A.M.	4.9	5.5
	P.M.	6.6	7.2
2	A.M.		
	P.M.		
3	A.M.	7.6	8.1
	P.M.	3.3	3.5
4	A.M.	36.4	43.6
	P.M.	66.8	64.2
5	A.M.	7.2	8.1
	P.M.	5.1	5.3

Vehicle speeds

Vehicle speeds were measured 50 ft downstream of the DFS. Mean vehicle speed was calculated as it represents a good measure of the central tendency that best resists the influence of fluctuation between different samples.

The field data indicated that over 95 percent of all drivers travel above the school speed limit of 15 mph. The mean vehicle speeds at all locations during the morning and afternoon school periods were closer to or above the 24-hour posted speed limit (25 to 30 mph) for that roadway before the DFS deployment. For example, mean vehicle speeds on New Hampshire Avenue (# 1) are more than twice the school zone speed limit (15 mph) and drivers tend to drive closer to the 24-hour posted speed limit of 30 mph. Mean vehicle speeds on Mount Olivet Road (# 2) are more than 1.8 times the school zone speed limit (15 mph) and drivers tend to drive closer to the 24-hour posted speed limit of 25 mph.

Mean vehicle speeds on Constitution Avenue (# 3) during the morning peak period is almost twice the school zone speed limit (15 mph) and exceed the 24-hour posted speed limit of 25 mph. Motorists take advantage of the one-way system and increase their speeds. One possible explanation is that drivers adjust their behavior in relation to the speeds of the other drivers in front of them and therefore perceive no violation of the law or any threat from enforcement.

Mean vehicle speeds on Pennsylvania Avenue (# 4) are consistent with the other sites and are close to the 24-hour posted speed limit of 30 mph, except in the morning peak period westbound when traffic congestion prevents drivers form traveling above 15 mph. Mean vehicle speeds on 25th Street (# 5) are similar to the other four study sites in that drivers tend to maintain a speed more consistent with the 24-hour posted speed limit of 25 mph.

In general, the mean vehicle speeds at most locations before DFS deployment were lowest where there is one travel lane) in each direction (Stanton Elementary School – 5, and Maury Elementary School – 3). At these locations the mean vehicle speeds average between 24 and 29 mph. As the number of travel lanes per direction increase so do the mean vehicle speeds. The curb lane was observed to be the slowest at Randle highlands Elementary School - 4, and Raymond Elementary School – 1.

Table 11 summarizes the statistics for the mean vehicle speeds before and after DFS deployment. No data was collected from location 3 (Maury Elementary School – eastbound, morning peak period) as Constitution Avenue is one-way westbound. Researchers used a z-test for means to assess the significance in the change of the mean vehicle speeds before and after DFS deployment. The null hypothesis being addressed was: There is no significant difference in the mean vehicle speeds before and after the DFS deployment (at the 0.05 level of significance).

Mean vehicle speeds at 12 of the 19 sites dropped after DFS deployment. However, at four of the nineteen periods, the z scores were outside the z critical (1.96 > Zc > -1.96).

Thus, the null hypothesis was rejected at locations 1 (northbound), 4 (westbound), and 5 (southbound); that there is no significant difference in the mean vehicle speeds being experienced before and after DFS deployment.

Table 11: Mean Vehicle speed before and after DFS deployment

		A.M. Period						P.M. Period					
Location		Before		After			Significant [1]	Before		After			Significant [1]
No.	Direction	SS	X_b	SS	X_A	Z-score	Yes/No	SS	X_b	SS	X_A	Z-score	Yes/No
1	Northbound	290	30.6	200	28.7	3.43	Yes	324	32.6	200	29.1	7.83	Yes
	Southbound	140	30.4	200	34.2	-4.44	No	136	31.6	200	33	-1.43	No
2	Westbound	210	27.2	100	26.1	1.74	No	281	28.2	109	27.9	0.57	No
	Eastbound	270	24.1	100	24.9	-1.34	No	373	27.7	100	27.2	1.01	No
3	Westbound	447	29.9	100	30.5	-0.88	No	88	24	100	28.3	-4.36	No
	Eastbound							171	24.8	100	24.9	-0.16	No
4	Westbound	194	15.6	300	15.3	0.52	No	450	32	300	25	12.81	Yes
	Eastbound	340	29.2	200	28.8	0.41	No	362	24.1	200	30.9	-8.38	No
5	Northbound	160	28.8	100	28.7	0.15	No	194	29.6	100	29.1	0.64	No
	Southbound	117	24.2	100	24.1	0.14	No	204	25.2	100	22.4	4.17	Yes

SS - Sample Size

x_b Mean vehicle speed before DFS deployment

x_a Mean vehicle speed after DFS deployment

1 - Significance level 0.5 (Z - Score for the difference between two means, $Z_c = 1.96$)

In a closer examination of the data and the locations where the mean vehicle speeds were significantly reduced, technicians observed that the DFS had good visibility, little or no sign clutter, no on-street parking, and at most two travel lanes. These observations by the research team compared well with the previous work by Ullman[8] and Chang[9]. The results as shown in Table 11 for locations 4 and 5 during the morning peak period were expected. Pennsylvania Avenue westbound – 4 experiences significant traffic congestion during the morning peak period hampering the motorist ability to drive faster. 25^{th} Street northbound – 5 have a high percentage of cut-through work related trips, and by their very nature are less observant of any type of speed reduction signs.

The research team determined that the effect of the DFS speed information was causing the majority of drivers to slow down a little in order for them to check their speedometer. Drivers wished to ensure that they were not driving more then 10 mph over the school zone speed limit of 15 mph, and thus was not in danger for being ticketed for speeding. This is a false presumption, but, nevertheless one that is often made. In any event, speedometer-checking does not necessarily diminish the potential usefulness of posted speed feedback information as a road safety intervention. The research team believes than any intervention that encourages drivers to be more aware of their speed is a step in the right direction.

Customer Satisfaction Results

Three sites were chosen to administer the survey; site selection was based on the ability to capture pedestrian traffic and adequate space for drivers to pull over safely. The locations selected were Raymond Elementary School, Stanton Elementary School, and Maury Elementary School. Table 12 indicates the number of completed surveys administered at each location.

Table 12: Completed surveys administered at each location

Survey Instrument	Raymond Elementary School	Stanton Elementary School	Maury Elementary School
Driver	23	18	16
Pedestrian	16	18	13

The customer satisfaction survey focused on the extent to which the DSF improved the levels of satisfaction with the users of that roadway system. The primary users of the affected roadway system are pedestrians and drivers and it was critical to measure satisfaction levels for both user groups to evaluate overall customer satisfaction. Appendix B provides a summary of all responses.

<u>Driver Feedback Discussion</u>

More than 60 drivers were stopped and surveyed; of the survey forms collected, only three forms were discarded for inaccuracies or lack of response. The data clearly indicated that the majority of vehicle trips made during the morning peak period are work-based (77 percent) as figure 7 shows. This supports the previous discussion that these trips are time-based and the drivers are more likely to violate the traffic control measures in place.

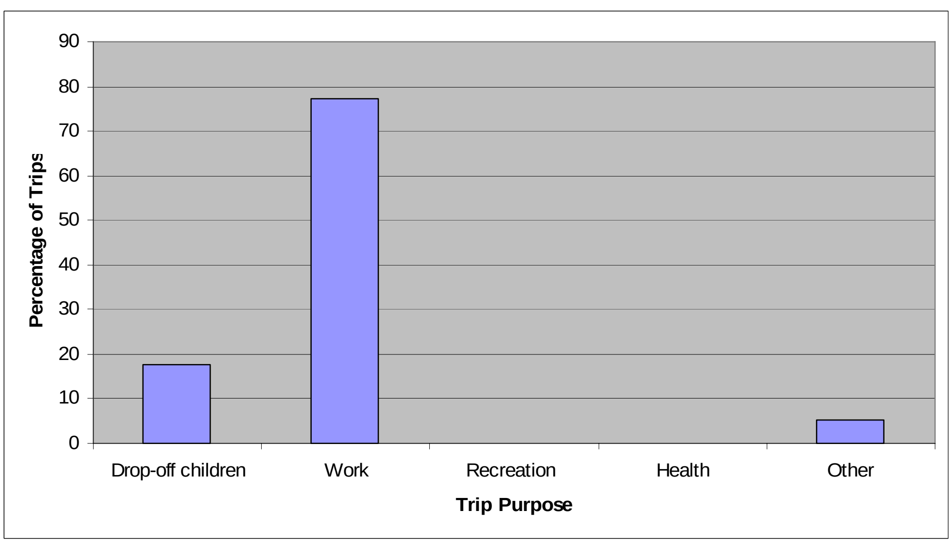


Figure 7: Trip Purpose

The fact that more than 61 percent of the drivers captured lived in the District of Columbia is important in that it helps to target outreach information on the DFS. Figure 8 illustrates the residence (State) of the driver.

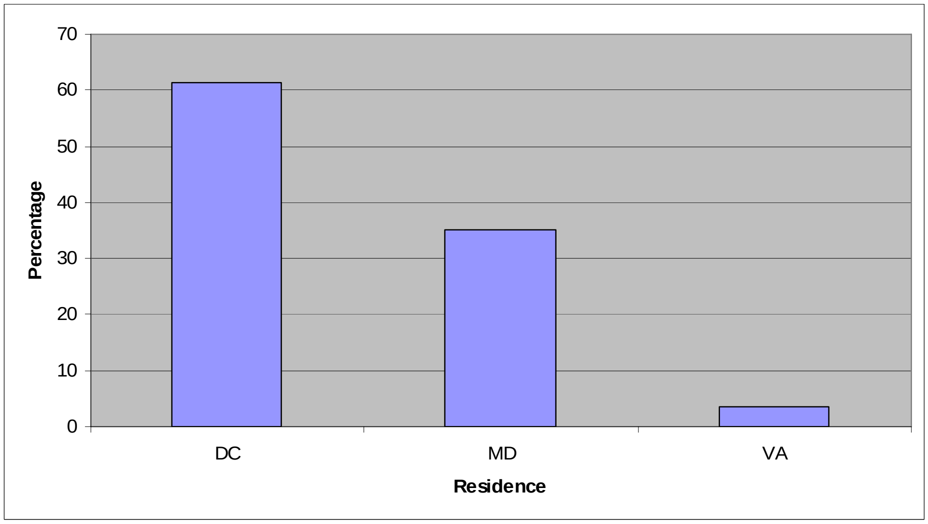


Figure 8: Home State of driver

The results of the driver survey indicate that more than 73 percent (see figure 9) of all drivers drive on the surveyed roads at least five times per week. It was critical that the drivers use the surveyed road on a regular basis in order to evaluate the DFS.

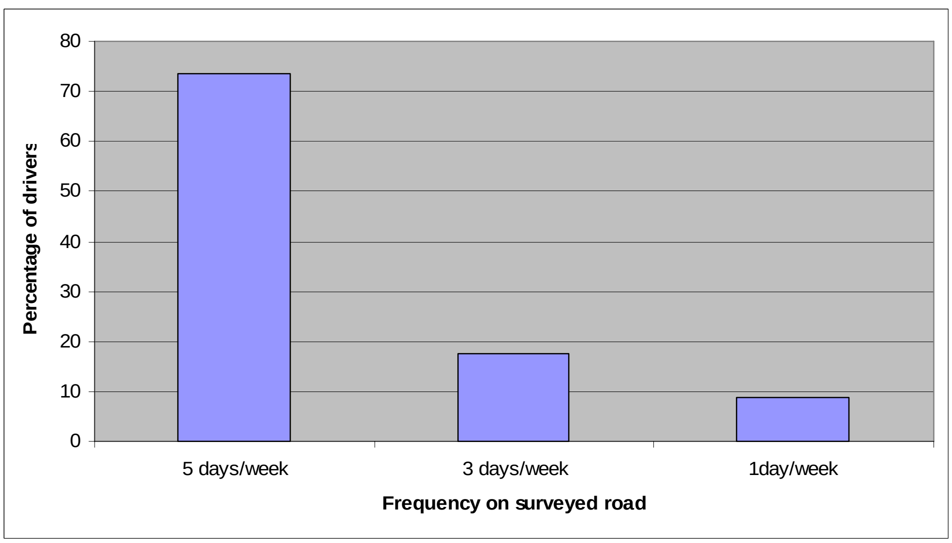


Figure 9: Frequency with which drivers drive on the surveyed roads

The data further indicates that more than 20 percent of drivers believe the speed limit was higher that 25 mph and they were not aware of the location being a school zone. This combined with the fact that more than 95 percent of the drivers were exceeding the 15 mph school zone speed limit supports the research team's discussion of "driver comparison" affecting driver speeds. Drivers consistently underestimate the speed of vehicles around them, and they travel at a similar speed to the lead vehicle. Drivers further perceive that driving above the speed limit is the "norm" and view their own speed violations as "normal or acceptable" driving behavior.

The driver feedback data also indicated that the DFS location and visibility is critical to ensuring driver compliance. Only 46 percent of drivers noticed the DFS, and more than 63 percent of those drivers indicated they reduced their vehicle speeds. This finding is significant in that any treatment or countermeasure that causes a driver to reduce speed have the potential to reduce the severity of pedestrian crashes.

Pedestrian attitude survey discussion

More than 52 pedestrians were stopped and surveyed, of these surveys, only five forms were discarded for inaccuracies or lack of response. The data clearly indicated that the majority of pedestrian trips made during the morning peak period were work-based (55 percent), as figure 10 shows. The author believes these trips are time-based and the pedestrian is more likely to take a greater risk in crossing the roadway using smaller traffic gaps.

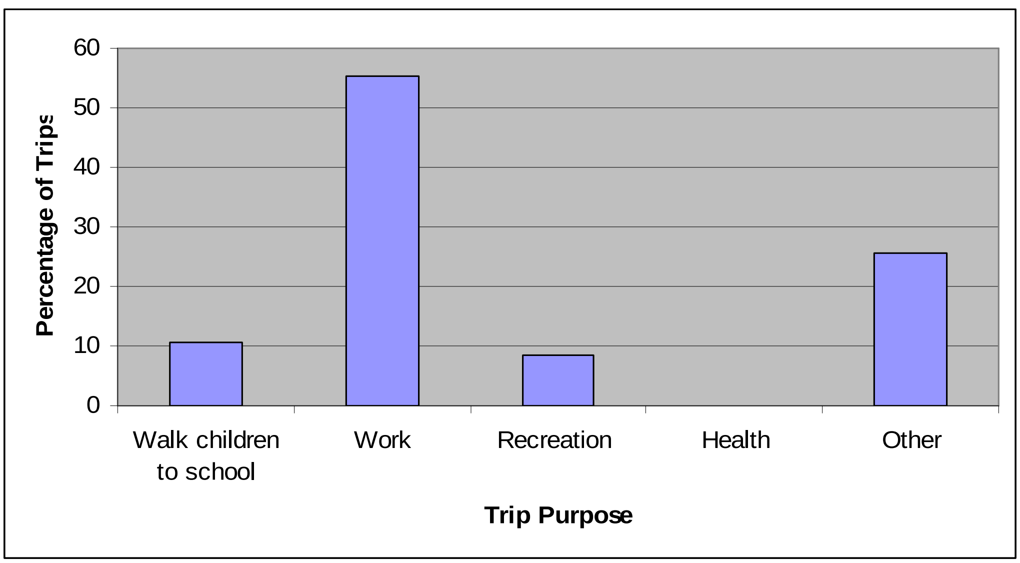


Figure 10: Trip Purpose

The majority of pedestrians surveyed (more than 60 percent) indicated the pedestrian crossings were unsafe and inconvenient. In addition, over 76 percent of the pedestrians indicated that the drivers do not yield to them and vehicles appear to be "speeding." When asked to rate the driver behavior toward the pedestrian on a sliding scale from 1 (very poor) to 5 (excellent), the majority of pedestrians rated the driver behavior as very poor (see figure 11).

These statistics reveal a critical need for treatments in school zones to slow vehicles and improve overall pedestrian safety. The data also reveals that three in four pedestrians do not feel any safer in crossing the street after the DFS was installed.

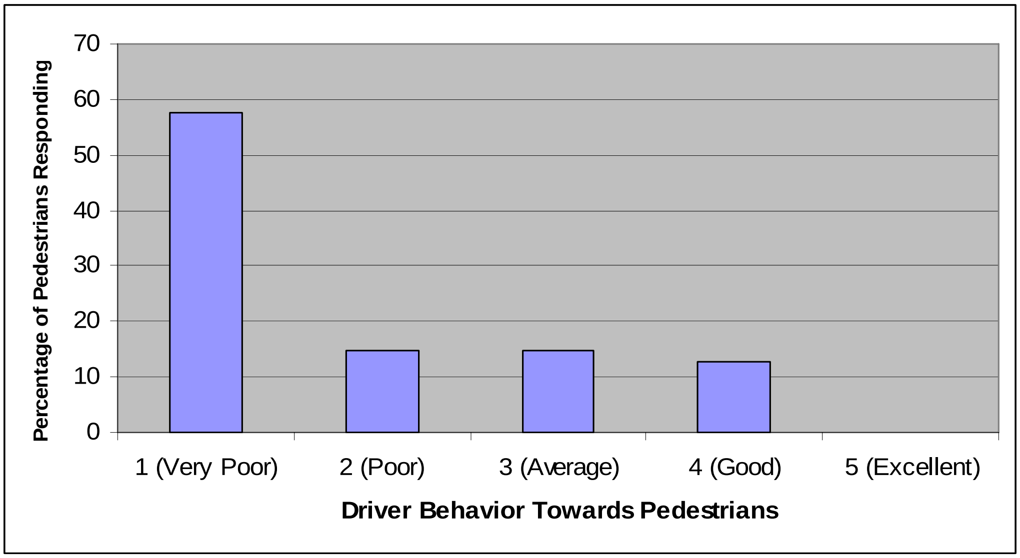


Figure 11: Pedestrian rating of behavior towards them

Conclusions and Recommendations

The results of the field studies at the five school locations where the DFS were installed indicate that such displays may have a significantly higher proportion of braking drivers. While this results in slower vehicle speeds at most locations, the reduction is only significant at just over 25 percent of the time.

It is not recommended that the DFS be deployed at all school locations. The field studies indicate that drivers have already factored into their vehicle speeds the presence of school zones. Although this speed is twice that of the existing school zone speed limit, the chance of achieving a more significant reduction is small. Based on the results of the field studies and together with the findings from other scientific studies[8,9], it is recommended that the DFS be deployed only in school zones where a speed study indicates that the mean vehicle speeds are 35 mph or greater. Following examination of all sites, it is believed that the DFS will achieve the greatest reduction in vehicle speeds when the following other conditions are also present:

- Locations where the visibility of the DFS is at least 150 to 200 ft and not blocked by trees, utility poles, or other obstacles.
- Locations with two-lane roads, one travel lane in each direction. A DFS that causes a motorist to reduce vehicle speed may also influence other motorists who are following behind.
- At locations with more than one travel lane in each direction, the DFS should be located over each lane. If this is not practical, then the DFS size should be increased to 36 in by 48 in.
- Locations with no on-street parking (If on-street parking exists, the DFS size should be increased to 36 in by 48 in.)
- Locations where the DFS conveys a clear and real need for the drivers to reduce speed. Similarly, the DFS maybe less effective at locations with an overabundance of driver information for a driver to process or too much sign clutter.

Finally, the DFS has good potential to reduce driver speeds and improve pedestrian safety when used as discussed above. However, an overabundance of the DFS can also mitigate any positive effects they may have.

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Appendix A: Customer Satisfaction Survey

	Driver Feedback on Driver Speed Feedback Signs Location :____ Date: ____________	**Code**
	Hello, my name is ______________ and I am working for KLS Engineering. I am obtaining driver feedback on the recently installed Driver Speed Feedback Sign. Any information you provide is confidential. Your response will help to make pedestrian travel safer in the District of Columbia. **Lane: 1 (Curb lane) 2 ( ) 3 ( )**	
1	**What is the purpose of your trip today?** a. Drop off child/children to school b. Work c. Recreation d. Health e. Other ____	
2	Gender (Observation)? Female ( ) Male ( ) What is your age? 0-16 **( )** 17-2 5 ( ) 26-35 ( ) 35-55 ( ) over 55 ( ) **Do** you live in … DC ( ) VA ( ) MD ( ) Other _______ **How** often do you drive here? 5 days/week ( ) 3 days/week ( ) 1 day/week ( ) **(Less than 1 day/week – Thank and Terminate)**	
3	**What is the Speed Limit of this road?** 15 mph ( ) 25mph ( ) 35mph ( ) 50mph ( ) Other: _______ **Did you know you just drove through a school zone?** Yes ( ) No ( ) **When the lights on the school signs are flashing is the speed limit…** 15mph ( ) 25mph ( ) 35mph ( ) **Do you think the speed limit should be higher?** Yes ( ) No ( ) **What speed do you think you were driving?** 0-15mph ( ) 15-25mph ( ) 25-40 mph ( ) 40-50 mph ( ) > 50 mph	
4	**Did you notice the signs that show your speed?** Yes( ) No ( ) **(If "NO" Thank and Terminate interview)** **Was it accurate?** Yes ( ) No ( ) **If "NO", was it?** Higher ( ) Lower ( ) **Did it cause you to adjust your vehicle speed?** Yes ( ) No ( ) **If "YES", was it?** Faster ( ) Slower ( )	

	Pedestrian Opinion on Driver Speed Feedback Sign	Code
	Pedestrian Opinion on Driver Speed Feedback Sign Location :________________________________ Date: ______________	**Code**
	Hello, my name is ____________ and I am working for KLS Engineering. I am obtaining pedestrian feedback on the recently installed Driver Speed Feedback Sign. This information is confidential. Your response will help to make pedestrian travel safer in the District.	
1	**What is the purpose of your walking trip today?** a. Drop off child/children to school b. Work c. Recreation d. Health e. Other ____________________	
2	Gender (observation)? Female ( ) Male ( ) What is your age? 0-16 **( )** 17-2 5 ( ) 26-35 ( ) 35-55 ( ) over 55 ( ) **<u>Do</u>** you live in … DC ( ) VA ( ) MD ( ) Other _______ **<u>How</u>** often do you walk here? 5 days/week ( ) 3 days/week ( ) 1 day/week ( ) **(Less than 1 day/week – Thank and Terminate)**	
3	**The pedestrian crossing** Did you find crossing here safe? Yes ( ) No ( ) Did you find the crossing convenient and easy? Yes ( ) No ( ) Do you generally cross at the crosswalk? Yes ( ) No ( ) **How would you rate the pedestrian crossing:** 1 (Very Poor) 2 (Poor) 3 (Good) 4 (Very Good) 5 (Excellent)	
4	**What do you think about the sidewalk area?** Adequate width Yes ( ) No ( ) Good condition Yes( ) No ( ) Overall was your walk pleasant and convenient? Yes ( ) No ( ) **How would you rate the surrounding sidewalks:** 1 (Very Poor) 2 (Poor) 3 (Good) 4 (Very Good) 5 (Excellent)	
5	**How do drivers behave?** Do drivers yield to people crossing the street? Yes ( ) No ( ) Do you think that drivers are speeding on this roadway? Yes ( ) No ( ) **How would you rate overall driver behavior?** 1 (Very Poor) 2 (Poor) 3 (Good) 4 (Very Good) 5 (Excellent)	
6	**The Driver Speed Feedback Sign was installed over __ months ago, since then have you noticed…** Any change in driver speeds? Increase ( ) Decrease ( ) None ( ) Do more drivers slow down so you can cross the street? Yes ( ) No ( ) Do you feel safer/ less-safer in crossing now ….Safer ( ) Less-safer ( ) No-change ( ) **Overall Rating on how safe you feel in crossing here** 1 (Very Poor) 2 (Poor) 3 (Good) 4 (Very Good) 5 (Excellent)	

Appendix B: Pedestrian and Driver Feedback Results

Pedestrian and Driver Feedback Results

Driver Feedback
At least 60 drivers were stopped and surveyed, of these only three survey forms were discarded for inaccuracies or lack of response. The following provides an overview on the driver responses:

- **Trip purpose:**
  - 77 percent of the drivers were on work related trips
  - 75 percent of the drivers surveyed were traveling in the lane adjacent to the DFS (only on roads with 2 or more lanes in the same direction)
- **Demographics:**
  - 63 percent of the drivers were females
  - 77 percent of the drivers were between the ages of 26 to 55 years
  - 61 percent of the drivers lived in the District of Columbia
  - 35 percent of the drivers lived in Maryland
  - 73 percent of the drivers drive on the surveyed roads at least five times per week
- **Driver understanding and compliance to the existing traffic controls:**
  - 20 percent of the drivers believe that the actual speed limit is higher than that posted (e.g. 25 mph)
  - 23 percent of the drivers did not know that they were driving through a school zone
  - 18 percent of the drivers believe that the speed limit in the school zone should be raised above the present restriction (15 mph)
  - 77 percent of drivers indicated that they were exceeding 15 mph
  - 33 percent of drivers indicated that they were exceeding 25 mph
- **Driver understanding and reaction to the DFS:**
  - 46 percent of drivers indicated that they noticed the DFS
  - 73 percent of the drivers that noticed the DFS indicated that it was an accurate reading
  - 63 percent of the drivers that noticed the DFS indicated that they adjusted their speed downwards

Pedestrian Feedback
At least 52 pedestrians were stopped and surveyed, of these only five survey forms were discarded for inaccuracies or lack of response. The following provides an overview on the pedestrian responses:

- **Trip purpose:**
  - 55 percent of the pedestrian were on their way to work
- **Demographics:**
  - 51 percent of the pedestrians were males
  - 72 percent of the pedestrians were 26 years or older
  - All the pedestrians lived in the District of Columbia
  - 87 percent of the pedestrians walked along the roadway at least five times per week
- **Walking environment:**
  - 60 percent of the pedestrians rated the pedestrian crossing as unsafe
  - 68 percent of the pedestrians rated the pedestrian crossing as not convenient
  - 68 percent of the pedestrians generally use the crossing facilities
  - 64 percent of the pedestrians rated the crossing facilities as below average
  - Over 90 percent of all pedestrians indicated that the sidewalk has adequate width, and is in good condition
- **Driver behavior prior to installation of DFS:**
  - Over 76 percent of all pedestrians indicate that drivers do not yield to them and appear to be speeding
  - 57 percent of pedestrians rated driver behavior towards pedestrians as very poor
- **Driver behavior after installation of DFS:**
  - Over 90 percent of pedestrians did not notice any change (slowing) in driver speeds
  - 75 percent of pedestrians indicated that they did not feel any safer in crossing the street